

VIX AND VIX FUTURES: A TOOL OF RISK REDUCTION AND DOWNSIDE PROTECTION FOR HEDGE FUNDS

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**VIX AND VIX FUTURES: A TOOL OF RISK
REDUCTION AND DOWNSIDE PROTECTION FOR
HEDGE FUNDS**

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Abstract

We analyze VIX, VIX futures and hedge funds. VIX is a measure of the implied volatility of S&P 500 index options. VIX futures performance is measured by the S&P 500 VIX Mid-Term Futures Index and the CBOE VIX Premium Strategy Index. Credit Suisse Hedge Fund Index and Hedge Fund Research Indices represent hedge funds performance.

In our project, we expand Dash and Moran (2005) by expanding the end period of survey from December 2004 to May 2014 and including two hedge fund databases, Credit Suisse and Hedge Fund Research. In addition, we conduct analyses on both VIX index and VIX futures indices, which are not included in the Dash and Moran (2005). Not only we check the addition of VIX index or VIX futures indices to hedge fund portfolios for risk reduction or downside protection, but also our analysis pays more attention to the period of 2008 financial crisis.

We find that broad-based hedge fund indices and most narrow hedge fund indices are negatively and asymmetrically correlated with VIX. Addition of VIX index as well as VIX futures indices protects hedge fund portfolios from major drawdowns and helps reduce risk.

Keywords: VIX; VIX Futures; Hedge Fund; Correlation;

Dedication

This project is dedicated to our families, for their continuous and unconditional support.

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Table of Contents

Approval	ii
Abstract	iii
Dedication	iv
Acknowledgements	v
Table of Contents	vi
1: Introduction.....	1
2: Literature Review	3
2.1 Hedge Funds and VIX.....	3
2.2 VIX Futures.....	4
2.3 Review of Dash and Moran.....	6
3: Data and Methodology.....	8
3.1 Hedge Fund Indices.....	8
3.2 VIX and VIX Futures Indices	8
3.3 Methodology	11
4: Results and Analyses – VIX Index.....	13
4.1 Correlations of Hedge Fund Returns and VIX Changes	13
4.1.1 Average Correlations.....	13
4.1.2 Rolling 30-Month Correlations	14
4.2 Efficient Frontiers with addition of VIX Index	16
4.3 Allocating VIX index	17
5: Results and Analyses – VIX Futures Indices.....	21
5.1 CBOE VIX Premium Strategy Index (VPD) and Financial Crisis.....	21
5.1.1 Correlations of Hedge Fund Returns and VPD Changes	21
5.1.2 Efficient Frontiers with addition of VPD Index	22
5.1.3 Shorting VPD	23
5.2 S&P 500 VIX Mid-term Futures Index (SPVIXMTR)	25
5.2.1 Correlation of Hedge Fund Returns and SPVIXMTR Changes.....	25
5.2.2 Allocating SPVIXMTR to Hedge Fund Index	26
6: Conclusions.....	30
7: Limitations.....	31
Appendices	32
Appendix 1: Code 1	33
Appendix 2: Code 2.....	39

Appendix 3: Code 3.....	44
Bibliography.....	48
Works Cited.....	48
Works Consulted	49

1: Introduction

Hedge funds represent one of the fastest growing asset classes in the financial markets with a 20% yearly growth rate. As of June 2013, the estimated size of the global hedge fund industry was 2.4 trillion USD. Traditionally, hedge funds were used as hedging techniques. However, nowadays the major purpose of hedge fund investors is to maximize returns instead of hedging risk. As a result, the volatility of hedge funds has become larger. Therefore, it is essential to find a way to reduce hedge fund risk and protect hedge funds.

In 1993, the Chicago Board Options Exchange (CBOE) introduced a new volatility index, VIX, and in 2003, the CBOE introduced a more detailed methodology for the VIX. VIX is a measure of the implied volatility of S&P 500 index options, and it is calculated on a real-time basis throughout each trading day. Since 1993, VIX has been considered one of the most important indicators of market volatility. Because VIX cannot be traded, VIX futures and VIX options were launched in 2004 and 2006, respectively, for those who want to trade in this instrument.

Dash and Moran (2005) discussed the relationship between VIX and broad-based hedge fund portfolios. They pointed out that VIX is negatively correlated to hedge fund return. They also found that when hedge fund return is positive, the correlation is weak, while when hedge fund return is negative, the correlation is strong. Therefore, they concluded that there is an asymmetric correlation between VIX and hedge fund return, and VIX could protect and diversify the hedge fund portfolios. Another finding was that a small allocation to VIX could reduce risk and protect the hedge fund portfolios during financial crisis.

In our paper, we explore the relationship between VIX and different hedge fund indices from two organizations, Credit Suisse and Hedge Fund Research. We first extend the data end date from 2005 to 2014, and we pay extra attention to 2008 financial crisis period (from 2007 to 2009). Other than the broad-based hedge fund portfolios, which

were used in Dash and Moran (2005), we also test the narrow hedge fund strategies. In addition, we test whether the allocation of VIX can protect hedge funds. Furthermore, we do similar analyses on VIX futures, which was suggested but not explored by Dash and Moran (2005). We use S&P 500 VIX Mid-term Futures Index and CBOE VIX Premium Strategy Index to represent VIX futures performance. Our finding is consistent with Dash and Moran's, and we also find that the relationship between VIX futures and hedge funds is similar with the relationship between VIX and hedge funds.

2: Literature Review

2.1 Hedge Funds and VIX

Because of the rapid growth rate of hedge funds, many studies on hedge funds have been done. Researchers are trying to find more ways to maximize the return and reduce the risk of hedge funds. Some researchers focused on VIX. They found a negative correlation between VIX and hedge fund returns, so they suggested that VIX could be used to reduce the hedge fund risk.

Morgan (2013) studied how can the statistical arbitrage affect the hedge fund performance, and he explored one of the hedge fund strategies, high frequency trading. Also, he discussed about their impact on the business environment. He found that although statistical arbitrage strategy produces more profit, it reduces the timelines of profitability at the same time.

Billion, Getmansky, and Pelizzon (2009) focused on the performance of hedge fund during financial crises, including the Long-Term Capital Management (LTCM) crisis of 1998, subprime mortgage crisis of 2007, and the 2008 Global financial crisis. They explored how the financial crises affect the hedge fund risk, and pointed out that liquidity, credit, and volatility risks are systematic risk factors for hedge funds. They found that the hedge fund volatility increased dramatically during financial crises, by studying eight hedge fund index strategies. Another finding was that the correlation between hedge fund strategies also increased during financial crises.

In the book edited by Gregoriou, Karavas, and Rouah (2003), the editors collected many articles that discussed about hedge funds returns, risks, and strategies in more details. The articles included both quantitative and qualitative analysis on hedge funds, and introduced some important issues faced by hedge fund investors and researchers.

Whaley (2009) gave us a general introduction on VIX. He introduced the history of VIX and how to calculate the VIX. Also, he explored the VIX in relation to the stock

market in quantitative respect. In addition, he claimed that VIX can be used as a predictor. Based on his research, VIX can predict the expected range of S&P 500 index returns in next 30 days. He double-checked the performance of VIX as a predictor by using historical data, and the result showed that VIX is a good predictor of the future S&P 500 index changes. This paper was focus on the exploration on VIX and S&P 500 index relationship, but it did not analyse the relationship between VIX and hedge funds.

Black (2006) studied on how to improve hedge fund risk exposures by using VIX. Usually the returns of hedge funds are not normally distributed, but the Sharpe ratio is based on the assumption of normal distribution. Therefore, we should not only focus on the mean, variance and Sharpe ratio, but we should also look at the skewness and kurtosis of the hedge funds returns. Skewness is a measure of symmetry of returns, while kurtosis is a measure of tails. When kurtosis is higher than three, the tail is fat, which means that there are more extreme returns than a normal distribution of equal variance. Investors always want to have positive skewness and low kurtosis, in order to maximize their profit and minimize their risk. However, most hedge fund returns have a lower skewness and higher kurtosis than S&P 500, even if they have higher Sharpe ratio.

According to Black's research, allocating a small portion of VIX can improve the skewness and kurtosis of hedge fund returns, and as a result, the risk of hedge fund investment can be reduced. He said that VIX not only hedge the traditional investment portfolios, but also can be used to hedge the alternative investment portfolio. To get this conclusion, he did some quantitative analysis on CBOE VIX and CSFB Hedge Fund Index. He found that there is a strong negative correlation between VIX and hedge funds. Therefore, allocating a long VIX position in investment portfolio can reduce the risk. Also, the data showed that the skewness, kurtosis, and correlation to the S&P 500 can be greatly improved by adding VIX into investment portfolio.

2.2 VIX Futures

Because VIX is an index that cannot be traded directly in practice, VIX futures were introduced in May 2004. VIX futures are similar with other futures contracts, which

are exchange-traded contracts on a future VIX level derived from a basket of S&P 500 stock index options. There are many different VIX futures contracts based on their maturity level, such as S&P 500 VIX Short-Term Futures Index, S&P 500 VIX Mid-Term Futures Index, and S&P 500 VIX Long-Term Futures Index.

Zhang and Zhu (2006) studied VIX futures by using the data from the CBOE web site. Because VIX cannot be traded, the non-arbitrage principle cannot be used to get the relationship between VIX and VIX futures. Therefore, they want to find a good way to price VIX futures. They built a model for VIX and VIX futures, and did a lot of quantitative analysis using the historical data from 1990 to 2005.

Szabo (2009) explored the portfolio diversification during 2008 financial crisis. He observed that the correlation between VIX and S&P 500 was extremely strong during financial crisis. Therefore, he got the same conclusion with Black (2006) that long VIX can reduce portfolio's risk. He built three portfolios: one is 100% equity, one is 60% equity and 40% bonds, and one is equity, bonds and alternative assets. Then he added 2.5% and 10% VIX futures to these three portfolios. He found that the VIX futures allocation can increase the portfolio returns and decrease the volatilities. The statistics showed that during financial crisis, the VIX futures can reduce losses dramatically. As a result, allocating of VIX futures in portfolios can diversify the investment and protect the investment during financial crisis.

Chen, Chuang and Ho (2010) also examined the diversification effects of VIX futures on investment portfolios. They found that allocating VIX-related assets can reduce the risk of portfolio, and the Sharpe ratios for portfolios with VIX-related assets are significantly higher than the portfolios with no VIX. Also, the correlations between VIX futures and portfolios are stronger, and the variances of portfolios with VIX futures are lower. Therefore, they concluded that investors can gain diversification benefits from investing in portfolios with VIX products, and also, the hedge fund managers can improve their performance by trading the VIX products.

2.3 Review of Dash and Moran

Our project is based on Dash and Moran (2005). Dash and Moran explored the relationship between VIX and hedge fund returns, and they also tested whether allocating VIX in portfolio can reduce the risk and provide downside protection to investment.

Dash and Moran used the Credit Suisse Hedge Fund Index (HFI) and the CBOE VIX data to do their analysis. The data time period was from 1995 to 2004. Note that Credit Suisse HFI has many narrow hedge fund strategies, but Dash and Moran only explored the broad-based hedge fund portfolio.

Dash and Moran first figured out that there is a negative correlation existed between HFI and VIX. Then, they drew a graph of rolling 30-month correlations of HFI with VIX, and found that the correlation is not stable. When the market went down, the correlation was strong, while when the market rose up, the correlation became weaker. Therefore, they conclude that the correlation between VIX and hedge fund returns is asymmetric.

Next, they allocated VIX to a hedge fund portfolio to see that whether VIX can improve hedge fund performance. They looked at the efficient frontier for an HFI and VIX portfolio first, and found that the best allocation of VIX should be between 0% and 10%. Based on this finding, they built three portfolios. The first one is HFI with no VIX, the second one is HFI with static 5% VIX, and the third one is HFI with tactical VIX. They defined the tactical VIX as following: When VIX increased by more than 20% in past quarter, they set the VIX allocation equal to 0%; when VIX decreased by more than 20% in past quarter, they set the VIX allocation equal to 10%; when the changes of VIX was between -20% and 20% in past quarter, they set the VIX allocation equal to 5%. They compared the cumulative returns, volatilities, Sharpe ratios, skewness and kurtosis of these three portfolios, and concluded that the tactical allocation of VIX gives the best outcome.

Finally, Dash and Moran suggested that VIX futures can be treated as one implement of the allocation strategy. Because there is not enough data of VIX futures at that time, they could not do the analysis on VIX futures. Also, they suggested that people

can study on the relationship between VIX and narrow hedge fund strategies to see whether VIX can help to improve narrow hedge fund strategies as well.

In our project, we expand Dash and Moran's paper by conducting following steps:

1. Expanding the end period of survey from December 2004 to May 2014.
2. Using two databases, Credit Suisse and Hedge Fund Research, and comparing both outcomes.
3. Testing both VIX index and VIX futures indices.
4. Checking whether the 2008 financial crisis impacted the relationship between VIX changes and hedge fund returns.
5. Checking the addition of VIX or VIX futures to hedge fund portfolios for risk reduction or downside protection.

3: Data and Methodology

We conduct our research at index level and use two hedge fund index databases and consider three indices as directional exposure to VIX. This section describes the data we use and the analysis steps we follow.

3.1 Hedge Fund Indices

We use the Credit Suisse Hedge Fund Indices (HFI), which have been used in Dash and Moran (2005), to represent returns to the universe hedge funds. The Credit Suisse HFI as the industry leading asset-weighted hedge fund index provides an accurate depiction of an investment in hedge fund. We include data from January 1998 to May 2014 to match the timeline of another hedge fund database we use. As Dash and Moran (2005) suggested, we also include strategy-based hedge fund indices in our research to narrow results. Those ten individual strategy indices are listed in our Results and Analyses part.

We also include the hedge fund indices from Hedge Fund Research (HFR) Database, one of the most comprehensive resources of hedge funds, to see whether Dash and Moran's results will still hold. We consider the investable HFRX Global Hedge Fund Index as the representation of the hedge fund universe. Four other strategy-based indices include HFRX Event Driven Index, HFRX Equity Hedge Index, HFRX Relative Value Arbitrage Index, and HFRX Macro/CTA Index. The available sample period is from January 1998 to May 2014.

3.2 VIX and VIX Futures Indices

Our research use the VIX index calculated using the new methodology and we include the index data from January 1998 to June 2014. Instead of only using VIX index, we find the S&P 500 VIX Mid-Term Futures Index (SPVIXMTR) and the CBOE VIX Premium Strategy Index (VPD). These investable indices offer a directional exposure to

VIX Futures. The SPVIXMTR measures a daily rolling long position in the fourth, fifth, sixth and seventh month VIX futures contracts. Introduced by Chicago Board Options Exchanges in 2007, the VPD tracks the performance of a strategy that invests in Treasury Bills and systematically sells one-month VIX futures. The SPVIXMTR has sample period from July 2009 to May 2014, and the VPD data is available from July 2004 to May 2014 including back-tested data.

Here we plot VIX index in Figure 1. It is clear that the VIX index increased a lot during 2008 financial crisis, while decreased when the economic was coming back. VIX outperformed significantly when market was declining.

Figure 1: VIX Close Price, January 1998 to May 2014

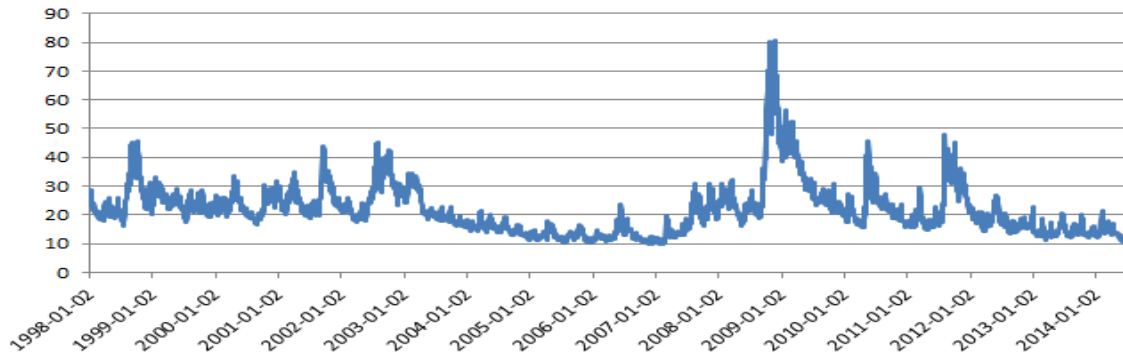


Figure 2 shows VPD was decreasing during 2008 financial crisis and increasing after that. Moreover, VPD follows an opposite trend to VIX.

Figure 2: VPD Value, July 2004 to May 2014



Figure 3 demonstrates that the SPVIXMTR follows the VIX from August 2009 to May 2014. They both went up around July 2010 and December 2011. After 2012 they both keep going down.

Figure 3: SPVIXMTR, August 2009 – May 2014



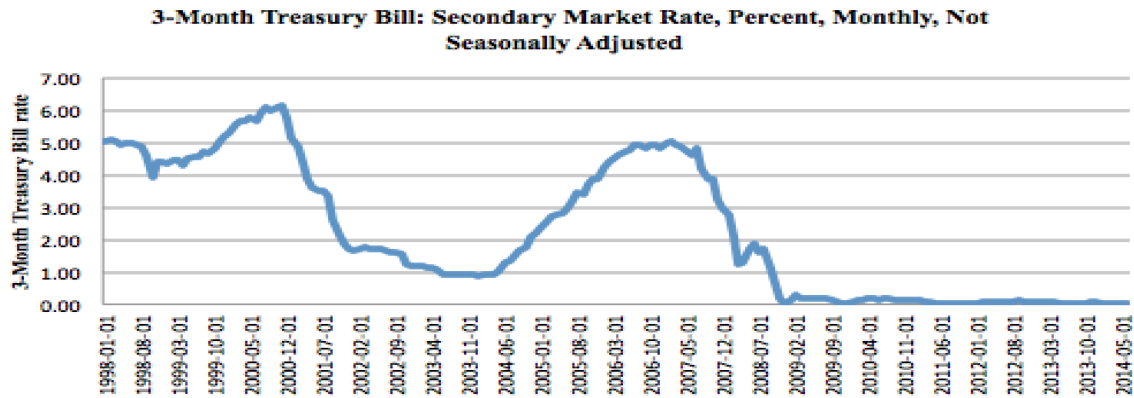
We summarize assets' annualized returns and standard deviations in Table 1. In Table 1 and in the following sections, HFI and HFRX stand for broad-based Credit Suisse Hedge Fund Indices and HFRX Global Hedge Fund Index respectively.

Table 1: Summary Statistics

	Annualized Return	Standard Deviation
January 1998 - May 2014		
VIX Index	-4.15%	66.45%
HFI Index	6.94%	6.63%
HFRX Index	5.33%	6.40%
July 2004 - May 2014		
VPD	9.74%	21.10%
HFI Index	6.14%	5.92%
HFRX Index	1.128%	6.32%
July 2009 - May 2014		
S&P 500 Futures Indexes	-30.92%	18.63%
HFI Index	7.978%	4.72%
HFRX Index	2.93%	4.18%

We find risk-free rate based on three-month Treasury bill yield. We assume the average of corresponding three-month Treasury bill yield is the risk-free rate for that period. As shown in Figure 4, Treasury bill rate has been very low since 2009. Therefore, we assume risk-free rate equals zero after 2009.

Figure 4: Three-Month Treasury Bill Rate



3.3 Methodology

As we mentioned before, our research bases on the Dash and Moran (2005). We use the similar methodology used by Dash and Moran (2005) but expand sample period and include more data sources. Here are the analysis steps we follow:

1. Measure correlations of VIX changes to hedge fund index returns
2. Plot efficient frontier with addition of VIX exposure to hedge fund index
3. Allocate VIX exposure to hedge fund index

More details regarding how we conduct our analysis steps are described here.

To measure the relationship of hedge fund returns to VIX Changes, we calculate average correlation and rolling 30-month correlations of broad-based hedge fund indices returns (HFI and HFRX) to VIX changes. Same calculations have been done with strategy-based indices.

In order to demonstrate the basic idea of adding VIX exposure to hedge funds, we draw efficient frontiers. Addition of VIX index as well as two kinds of VIX futures indices to the HFI and HFRX are considered.

To further access the risk protection or diversification effect of VIX exposure, we first add VIX index exposure to HFI and HFRX. Although VIX is not investable, the performance of VIX futures and options are based on the current expectation of VIX. Therefore, we can see the basic effect of combining VIX index and hedge fund index. To

these hedge fund indices, static and tactical allocation strategies are used. When construct tactical allocation, we rely on the mean reversion nature of VIX.

After finishing with VIX index, we conduct same analysis steps on two VIX futures indices (SPVIXMTR and VPD). As stated by Szado (2009), although the prices of VIX futures are based on the current expectation of VIX, the volatility of VIX futures is much lower than that of VIX index. In addition to the fact that VIX index is not investable we have to allocate investable VIX futures indices to hedge fund index.

For the sake of clarity we discuss each specific allocation strategy in our Results and Analyses part. Moreover, our analysis was performed using all kinds of allocation weights but not all results are included in our report. We only demonstrate several numerical examples. In addition to the whole sample period (1998 to 2014), a sub-period of 2008 financial crisis is discussed separately.

It is worth noting that our research is intended to access the impacts of VIX and VIX Futures exposure. Therefore, we focus on demonstrating the possibility of combining VIX or VIX futures to hedge funds for risk reduction or downside protection, same as Dash and Moran (2005). We do not intend to find the optimal VIX Futures investment strategy.

4: Results and Analyses – VIX Index

4.1 Correlations of Hedge Fund Returns and VIX Changes

4.1.1 Average Correlations

Table 2 summarizes the average correlations of VIX changes to Credit Suisse Hedge Fund Indices. We see negative average correlations from HFI as well as from most individual strategy indices. However, Dedicated Short Bias Hedge Fund Index and Managed Futures Hedge Fund Index have positive average correlations.

Table 2: Average Correlations of Credit Suisse Hedge Fund Indices
Returns to VIX Changes, January 1998 to May 2014

Credit Suisse Hedge Fund Index (HFI)	-0.4369
Credit Suisse Convertible Arbitrage Hedge Fund Index	-0.3606
Credit Suisse Dedicated Short Bias Hedge Fund Index	0.5536
Credit Suisse Emerging Markets Hedge Fund Index	-0.4963
Credit Suisse Equity Market Neutral Hedge Fund Index	-0.0976
Credit Suisse Event Driven Hedge Fund Index	-0.5355
Credit Suisse Fixed Income Arbitrage Hedge Fund Index	-0.5142
Credit Suisse Global Macro Hedge Fund Index	-0.1137
Credit Suisse Long/Short Equity Hedge Fund Index	-0.5375
Credit Suisse Managed Futures Hedge Fund Index	0.0427
Credit Suisse Multi-Strategy Hedge Fund Index	-0.3457

Table 3 summarizes the average correlations of HFRX Hedge Fund Indices returns to VIX changes. Obviously, we only see negative average correlations.

Table 3: Average Correlations of HFRX Hedge Fund Indices
Returns to VIX Changes, January 1998 to May 2014

HFRX Global Hedge Fund Index (HFRX)	-0.4146
HFRX Event Driven Index	-0.5680
HFRX Equity Hedge Index	-0.5368
HFRX Relative Value Arbitrage Index	-0.3584
HFRX Macro/CTA Index	-0.0855

4.1.2 Rolling 30-Month Correlations

Figure 5 shows the rolling 30-month correlations of Credit Suisse Hedge Fund Indices with VIX. The VIX is negatively correlated with HFI during the whole sample period. Most individual strategy indices follow the HFI demonstrating negative correlations. For Dedicated Short Bias, VIX is only positively correlated even though its pattern is very similar with HFI's. Fixed Income Arbitrage and Multi-Strategy are positively correlated with VIX before 2007, and negatively correlated with VIX after 2007. There are several strategies follow very different patterns, including Managed Futures and Equity Market Neutral.

Figure 5: Rolling 30-Month Correlations of Credit Suisse HFI with VIX

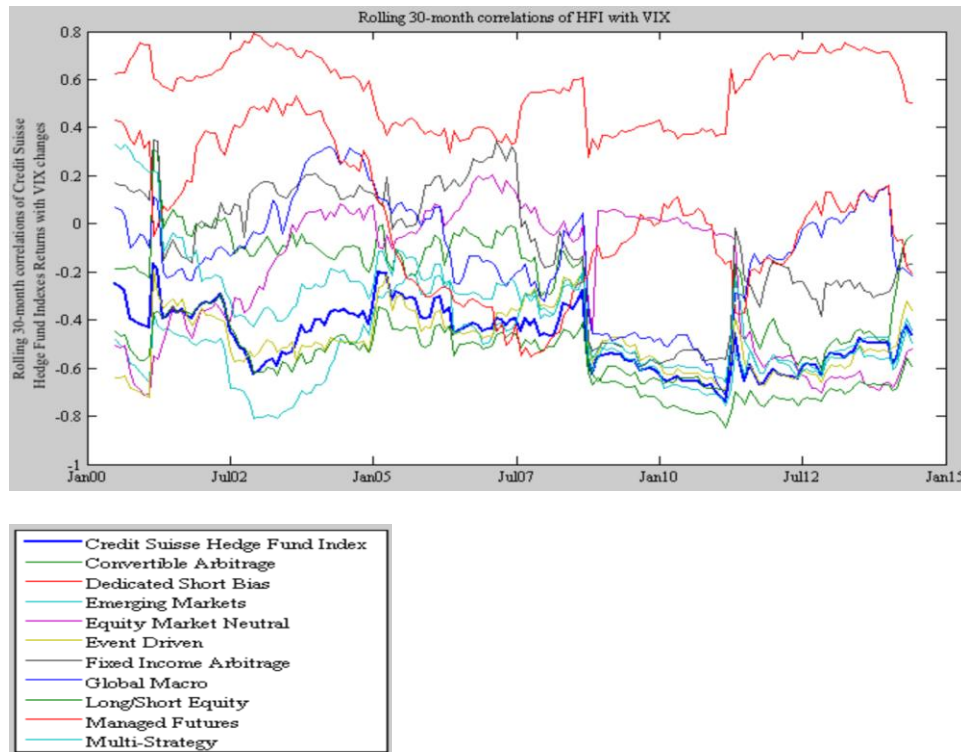
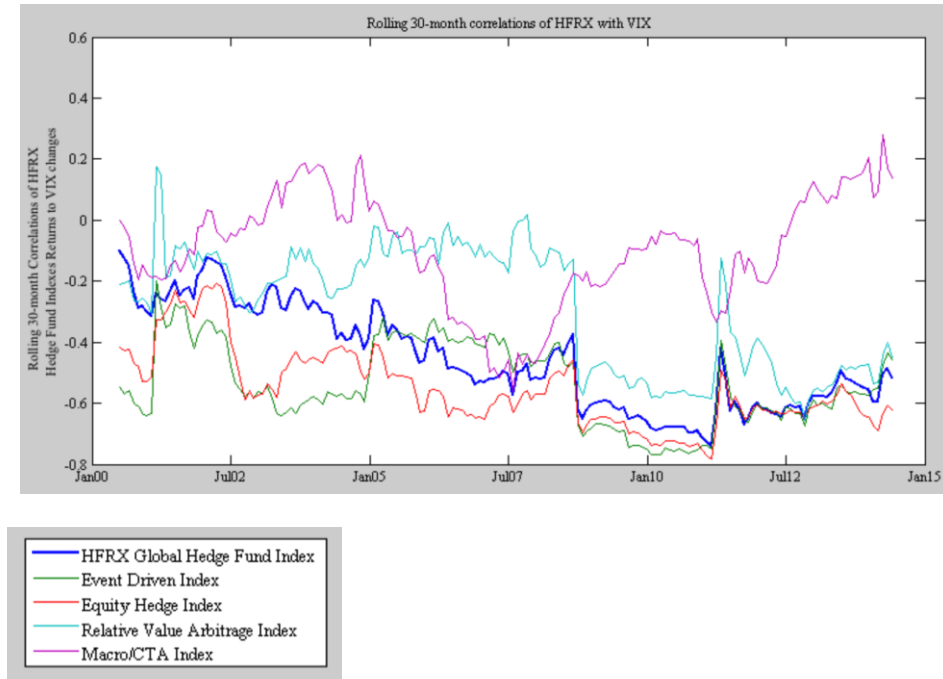


Figure 6 shows the rolling 30-month correlations of HFRX Hedge Fund Indices with VIX. HFRX Macro/CTA Index is the only index that demonstrates a different pattern than other four indices. The other four follow a same pattern and are negatively correlated to VIX. There are few times that Relative Value Arbitrage is positively correlated to VIX.

Figure 6: Rolling 30-Month Correlations of HFRX Hedge Fund Indices with VIX



Asymmetry in correlations can be seen from both Figure 5 and Figure 6. During 2008 financial crisis, the negative correlations are particularly strong for most indices. Moreover, not only most indices show stronger negative correlations and a same pattern during that period but also their correlations converge together more closely than they were before the crisis. Those do not demonstrate the same character might be explained by the strategy they follow.

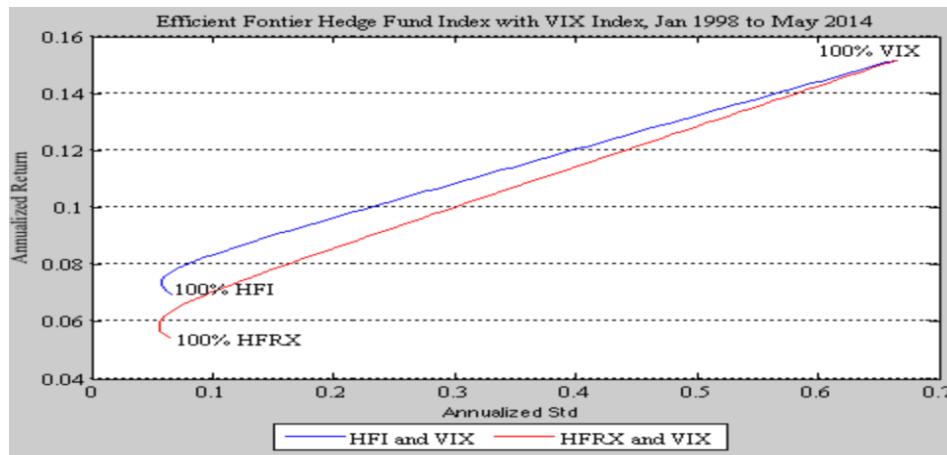
Low (2004), and Hibbert, Daigler, and Dupoyet (2008) suggested that investors' behavioural could be one possible reason of the asymmetric correlation. In their opinion, current negative return causes fear of more market declines in the future. Therefore, when market declines, the increment of volatility (VIX) is much more than the decrement of VIX during market advances. This is the reason that VIX is also called "fear index" (Lachini, 2014). Moreover, Whaley (2008) constructs a regression to confirm that the relation between VIX changes and the stock market is asymmetric. Another possible explanation for the asymmetric correlation is investors' demand for portfolio insurance (Whaley, 2008, Swedroe, 2013). If investors fear of more declines, their demand for stock returns and portfolio insurance will increase. Therefore, stock prices will decrease more and volatility will increase more (Whaley, 2008, Swedroe, 2013).

Overall, results on both Credit Suisse Hedge Fund Indices and Hedge Fund Research Indices are consistent with Dash and Moran (2005), that broad-based hedge fund indices are negatively correlated with VIX index. The asymmetric correlation suggests that diversification benefit or risk protection effect from adding VIX should have greater effect when in major crisis. Meanwhile, the convergence character provides support for allocating VIX to most individual strategy hedge funds. As most individual strategy indices have similar rolling correlations to HFI or HFRX, allocating VIX to individual strategy index should work as well as allocating VIX to broad-based hedge funds. In the following two allocation sections, we focus on the two representative broad-based hedge fund indices, HFI and HFRX.

4.2 Efficient Frontiers with addition of VIX Index

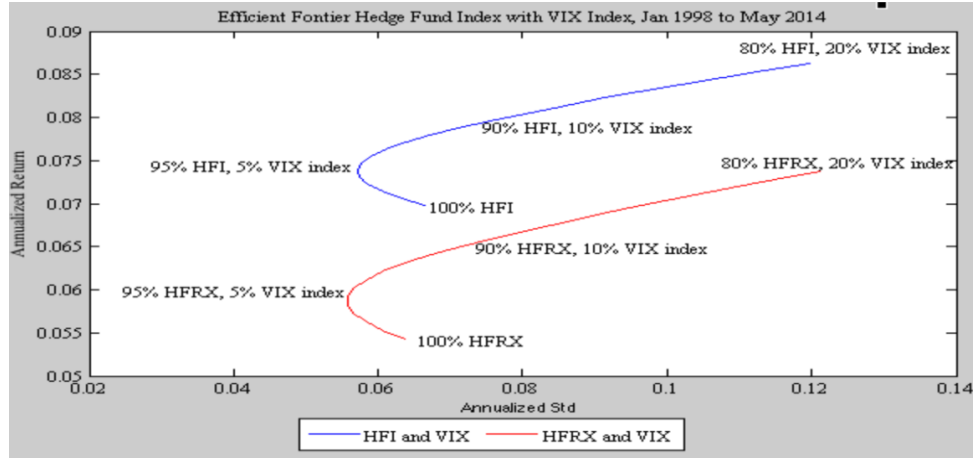
We can see the idea of adding VIX exposure to hedge funds can benefit the portfolio from Figure 7. With the addition of VIX, returns of HFI as well as HFRX are increasing with risk decreasing. After reaching the minimum risk point, returns are increasing with risk also increasing.

Figure 7: Efficient Frontier with Addition of VIX Index



Take a closer look at Figure 7, Figure 8 illustrates that the addition of up to 5% of VIX index gives us a portfolio that is efficient. There are no efficient portfolios with VIX allocation less than 5%. The diversification benefits are quite clear in those figures.

Figure 8: Efficient Frontier with Addition of VIX Index, weights 0% to 20%



Dash and Moran (2005) plotting an efficient frontier shows the diversification effect of adding VIX to HFI. Here we have demonstrated that with the addition of VIX exposure both HFI and HFRX can be benefited in a similar manner.

4.3 Allocating VIX index

As we found in the last section, addition of up to 5% VIX constructs an efficient portfolio. In addition, we do not want to add to much risk, therefore we choice to allocate VIX from 5% to 10%. Here are our four allocation combinations.

1. No VIX index
2. Static 5% VIX index
3. Static 10% VIX index
4. Tactical 0-10% VIX index

For the tactical strategy, we start with 5% VIX exposure. Based on the risk aversion nature of volatility and Dash and Moran's paper, if in the past quarter VIX increased by more than 20%, we cut down VIX allocation to 0%. If in the past quarter VIX decreased by more than 20%, we increase VIX allocation to 10%. If VIX changes are between +20% and -20%, we keep the VIX allocation steady at 5%.

Table 4 summarizes performances of portfolios with VIX exposure. In general, portfolios with VIX exposure outperform portfolios with no VIX. Skewness and kurtosis

are improved when there is VIX addition. From January 1998 to May 2014, portfolios with VIX exposure outperform with higher annualized returns, higher Sharpe ratios, and lower annualized standard deviations than portfolios with no VIX. The diversification effect is clearly demonstrated.

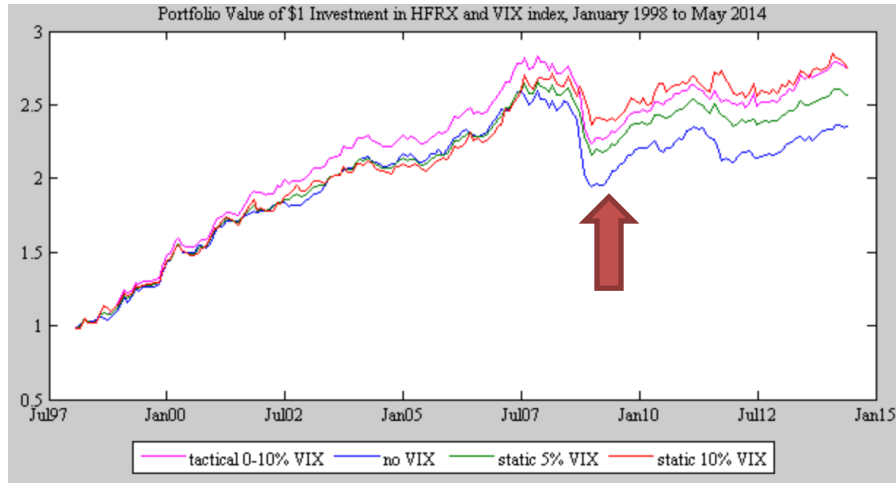
Table 4: Summary of Portfolios with VIX Index

		HFI				HFRX			
		no VIX	static 5% VIX	static 10% VIX	tactical 0-10% VIX	no VIX	static 5% VIX	static 10% VIX	tactical 0-10% VIX
Risk-free rate: 2.224%									
January 1998 - May 2014	Annualized Returns	6.92%	7.36%	7.80%	7.84%	5.37%	5.89%	6.41%	6.36%
	Annualized Std	0.067	0.057	0.067	0.060	0.064	0.056	0.067	0.061
	Sharpe Ratio	0.705	0.898	0.829	0.930	0.492	0.657	0.620	0.682
	Skewness	-0.489	0.324	0.332	0.186	-0.670	0.280	0.563	-0.341
	Kurtosis	7.225	7.426	5.791	6.966	8.187	5.777	3.584	8.334
Risk-free rate: 1.956%									
January 2007 - December 2009	Annualized Returns	2.92%	5.28%	7.64%	4.25%	-2.85%	-0.20%	2.45%	-1.26%
	Annualized Std	0.083	0.064	0.074	0.071	0.089	0.067	0.072	0.078
	Sharpe Ratio	0.116	0.515	0.763	0.323	-0.537	-0.320	0.068	-0.413
	Skewness	-1.200	-0.706	-0.084	-1.204	-1.625	-1.096	-0.094	-1.976
	Kurtosis	4.419	2.855	2.943	4.634	6.276	4.225	2.409	8.953
Risk-free rate: 0.758%									
January 2008 - December 2009	Annualized Returns	-1.63%	-0.10%	1.42%	-1.44%	-6.43%	-4.66%	-2.89%	-6.04%
	Annualized Std	0.093	0.068	0.072	0.076	0.100	0.071	0.069	0.085
	Sharpe Ratio	-0.256	-0.127	0.093	-0.288	-0.718	-0.764	-0.526	-0.804
	Skewness	-0.964	-0.501	-0.334	-1.067	-1.553	-1.074	-0.249	-2.042
	Kurtosis	3.437	2.398	2.437	3.875	5.296	3.857	2.046	8.146

We also analyse the effect of VIX index in two sub-periods (January 2007 - December 2009, January 2008 - December 2009). Same as we expected, both tactical portfolios and static portfolios outperform portfolios without VIX exposure on annualized returns and standard deviations. The tactical strategy is not necessary outperform the static portfolios as we do not intend to find an optimal strategy. However, during the crisis, the negative Sharpe ratios do not tell us more information since the returns are generally very small or negative.

Figure 9 plots cumulative portfolio values of investing \$1 since January 1998 with four strategies, no VIX, 5% VIX, 10% VIX, and tactical 0-10% VIX.

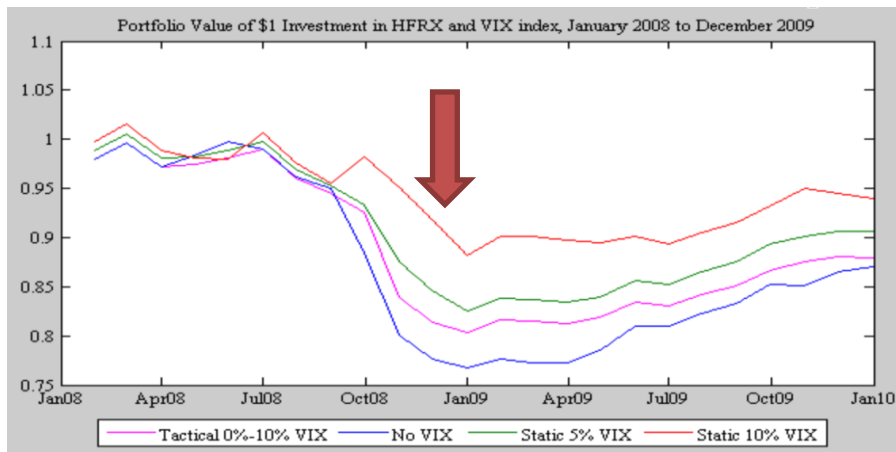
Figure 9: Addition of VIX Index to Hedge Fund Index



It is not hard to tell from Figure 9 that the portfolio value of no VIX exposure is smaller than the portfolio value with VIX exposure. In addition to the value differences at the end of the period, it is worth noting that the values of those four portfolios start to diverge when there is a major crisis. Before the crisis, we do not see significant differences among those values. Figure 9 confirms the risk protection effect of VIX and it works well especially during bad times.

From Figure 10 we can closely look at the risk protection effect of VIX.

Figure 10: Addition of VIX Index to Hedge Fund Index under Crisis



In this section, we explore the relationship between VIX and different hedge fund indices from two organizations, Credit Suisse and Hedge Fund Research, and we pay special attention to financial crisis period. Our finding is consistent with Dash and Moran (2005).

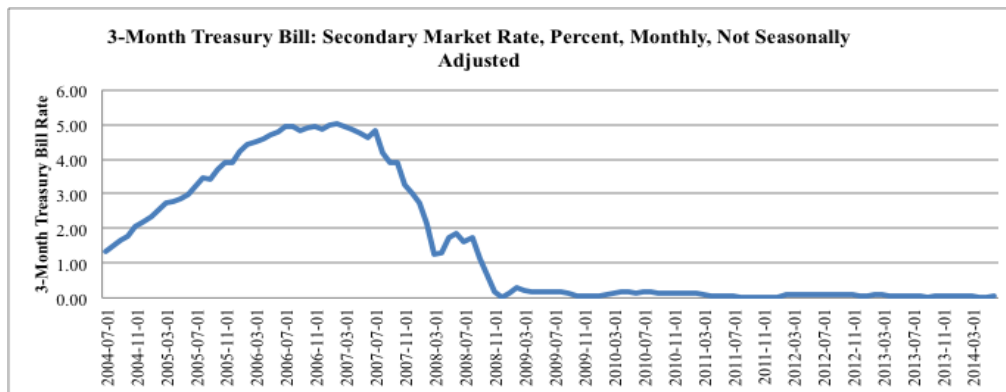
In the next section, as another expansion of Dash and Moran (2005), we explore the relationship between VIX futures index and hedge fund index, and focus on testing the possibility of adding investable VIX futures indices to hedge fund indices.

5: Results and Analyses – VIX Futures Indices

5.1 CBOE VIX Premium Strategy Index (VPD) and Financial Crisis

The VPD tracks the value of investing in both Treasury Bills and shorting one-month VIX futures. Before we utilise the VPD index, since returns of Treasury bills before 2008 are relatively high (Figure 11) we adjust VPD returns by subtracting corresponding three-month Treasury bills returns to capture the effects of investing only in VIX futures.

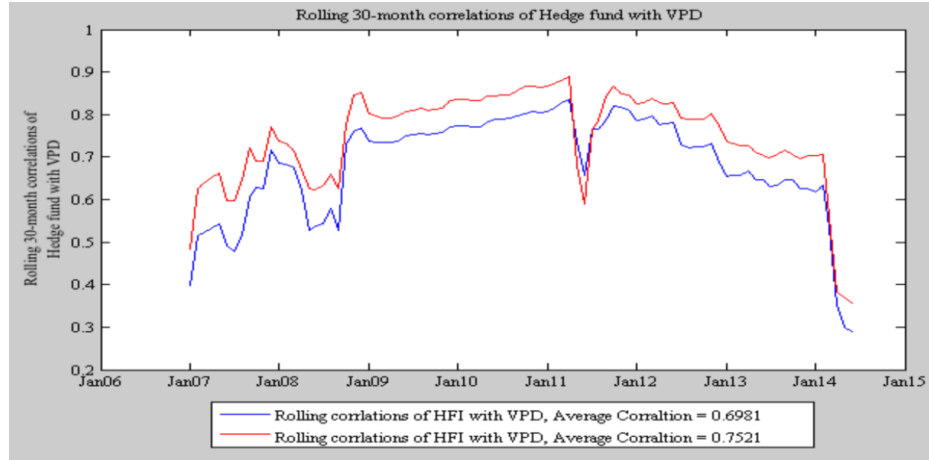
Figure 11: Three-month Treasury Bills Rate



5.1.1 Correlations of Hedge Fund Returns and VPD Changes

The average correlation of HFI and VPD is 0.6981 and the average correlation of HFRX and VPD is 0.7521. As can be seen from Figure 12, the 30-month rolling correlations of HFI or HFRX and VPD are positive. Especially during the 2008 financial crisis, the positive correlations get larger. The positive correlations, just as we expected, can be explained by the short VIX futures strategy using by the VPD index. If we construct a portfolio by only shorting the VPD, then we will be able to get long exposure of VIX futures and our portfolio will be negatively correlated to HFI or HFRX.

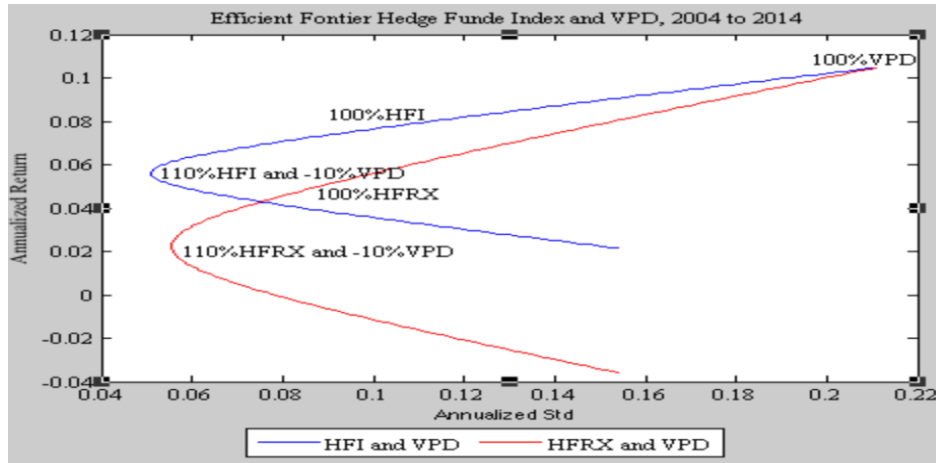
Figure 12: Rolling 30-Month Correlations



5.1.2 Efficient Frontiers with addition of VPD Index

We can see the idea of combining VPD and hedge fund index can benefit the portfolio from Figure 13. Take a closer look at Figure 13, it illustrates that short 10% of VPD gives us a portfolio that is less risky but still efficient. There are no efficient portfolios shorting VPD more than 10%.

Figure 13: Efficient Frontier with Addition of VPD



Based on our analyses on VIX index, we need a long exposure of VIX to benefit our portfolio. As VPD is positively correlated with hedge fund indices, the short strategy observed from Figure 13 is consistent with our expectation.

5.1.3 Shorting VPD

Based on the efficient frontier we plotted, shorting 0% to 10% VPD constructs an efficient portfolio. In addition, we do not want to sacrifice too many returns for reducing risk, therefore we choice to short VPD from 5% to 10%. Here are our portfolios:

1. No VPD
2. Static short 5% VPD
3. Static short 10% VPD
4. Tactical short 0-10% VPD

We start with shorting 5% VPD. Based on the risk aversion nature of volatility, if in the past quarter VPD increased by more than 20%, we stop shorting VPD (weight = 0%). If in the past quarter VPD decreased by more than 20%, we short more VPD (weight = -10%). If VIX changes are between +20% and -20%, we keep the VPD exposure steady at -5%.

Table 5 summarizes performances of portfolios with and without VPD. In general, portfolios with VPD outperform portfolios with no VPD. However, skewness and kurtosis are not improved.

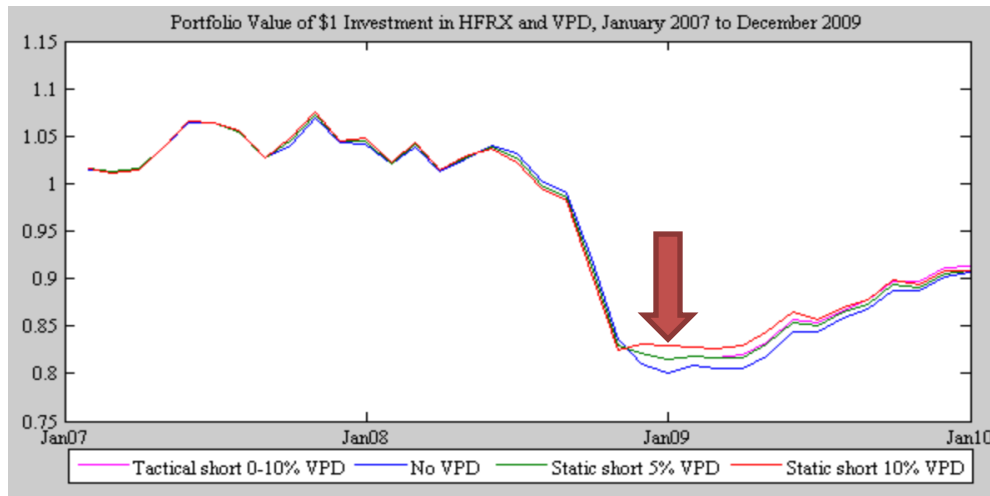
Table 5: Summary of Portfolios with VPD

		HFI				HFRX			
		no VPD	static short 5% VPD	static short 10% VPD	tactical short 0-10% VPD	no VPD	static short 5% VPD	static short 10% VPD	tactical short 0-10% VPD
Risk-free rate: 1.956%									
Jan 2007 - Dec 2009	Annualized Returns	2.92%	3.23%	3.53%	3.42%	-2.85%	-2.83%	-2.81%	-2.62%
	Annualized Std	0.083	0.081	0.081	0.081	0.089	0.088	0.090	0.088
	Sharpe Ratio	0.116	0.157	0.195	0.181	-0.537	-0.541	-0.532	-0.517
	Skewness	-1.200	-1.225	-1.283	-1.255	-1.625	-1.687	-1.674	-1.705
	Kurtosis	4.419	4.829	5.249	4.864	6.276	6.450	6.205	6.478
Risk-free rate: 0.758%									
Jan 2008 - Dec 2009	Annualized Returns	-1.63%	-1.52%	-1.41%	-1.23%	-6.43%	-6.56%	-6.69%	-6.24%
	Annualized Std	0.093	0.090	0.089	0.090	0.100	0.098	0.099	0.098
	Sharpe Ratio	-0.256	-0.254	-0.243	-0.221	-0.718	-0.747	-0.754	-0.713
	Skewness	-0.964	-1.035	-1.145	-1.069	-1.553	-1.656	-1.658	-1.676
	Kurtosis	3.437	3.937	4.417	3.949	5.296	5.595	5.444	5.614

When we compare Table 5 with Table 4, we find that under same period portfolios adding VIX index are outperform portfolios shorting same portion of VPD. This result can easily be explained by the gap between theory and practice. VIX products that can mimic VIX bring possibilities of combining VIX to hedge funds for risk reduction and downside protection (Dash and Moran, 2005). Although VIX futures are based on spot VIX, they have different characteristics (Szado, 2009), which give VIX futures and VIX index different returns and volatilities. The statistics of Table 4 and Table 5 demonstrate possibilities of combining VIX futures to hedge funds for risk reduction and downside protection, but also show the impacts of VIX products can hardly achieve or outperform the impacts of VIX spot.

Figure 14 shows the portfolio value of \$1 investment in HFRX with and without VPD exposure from January 2007 to December 2009. Before the crisis those four portfolios follow the same path with little deviations. Until the end of 2008, we do not see significant differences among those values. The values of those four portfolios start to diverge when there is a major crisis. Same as Figure 9 and Figure 10, Figure 14 confirms the risk protection effect of VPD and it works well under crisis.

Figure 14: Addition of VPD to Hedge Fund Index Under Crisis



5.2 S&P 500 VIX Mid-term Futures Index (SPVIXMTR)

5.2.1 Correlation of Hedge Fund Returns and SPVIXMTR Changes

Table 6 and Table 7 illustrate that the relationship between SPVIXMTR and hedge funds is similar with the relationship between VIX and hedge funds. The VIX futures index has a strong negative correlation with the broad-based HFI and HFRX. Also, it is negatively correlated with most narrow hedge fund strategies, and we find that the correlation patterns are similar with the one with the broad-based hedge fund index. Therefore, we use the broad-based hedge fund index to represent all hedge fund strategies in our following analysis.

Table 6: Average Correlations of Credit Suisse Hedge Fund Indices Returns to SPVIXMTR changes, August 2009 to May 2014

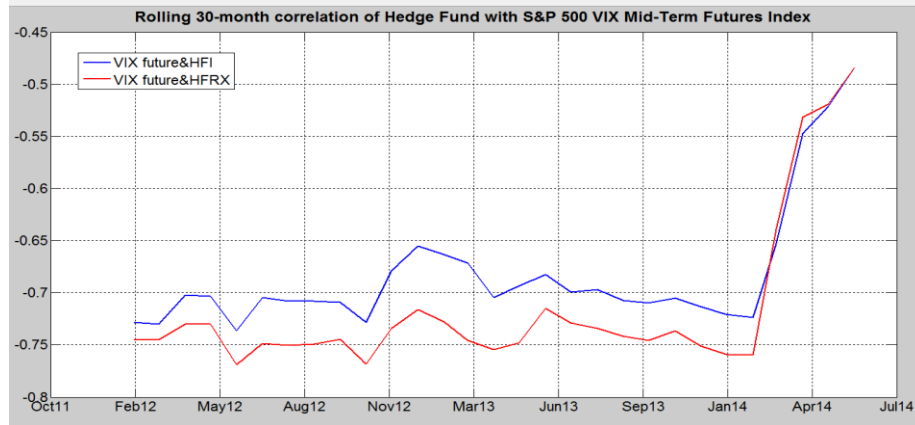
Credit Suisse Hedge Fund Index	-0.6449
Credit Suisse Convertible Arbitrage Hedge Fund Index	-0.4477
Credit Suisse Dedicated Short Bias Hedge Fund Index	0.6545
Credit Suisse Emerging Markets Hedge Fund Index	-0.6301
Credit Suisse Equity Market Neutral Hedge Fund Index	-0.5806
Credit Suisse Event Driven Hedge Fund Index	-0.6858
Credit Suisse Fixed Income Arbitrage Hedge Fund Index	-0.3172
Credit Suisse Global Macro Hedge Fund Index	-0.0927
Credit Suisse Long/Short Equity Hedge Fund Index	-0.7112
Credit Suisse Managed Futures Hedge Fund Index	-0.0867
Credit Suisse Multi-Strategy Hedge Fund Index	-0.7257

Table 7: Average Correlations of HFRX Hedge Fund Indices Returns to SPVIXMTR changes, August 2009 to May 2014

HFRX Global Hedge Fund Index	-0.6723
HFRX Event Driven Index	-0.0500
HFRX Equity Hedge Index	-0.6692
HFRX Relative Value Arbitrage Index	-0.6406
HFRX Macro/CTA Index	-0.5421

Figure 15 represents the rolling 30-month correlations of hedge funds with SPVIXMTR. From January 2014, the correlations between SPVIXMTR and become weaker. It might be caused by the economic recovery in US, and the returns of hedge funds are more stable than before. Therefore, we can conclude that there is a negative, asymmetric relationship between SPVIXMTR and hedge funds.

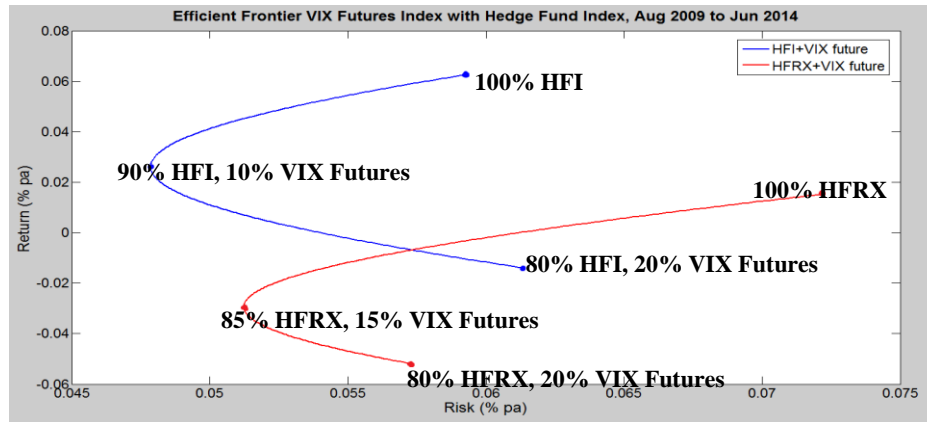
Figure 15 Rolling 30-Month Correlations of Hedge Fund Index with SPVIXMTR



5.2.2 Allocating SPVIXMTR to Hedge Fund Index

In order to determine how much SPVIXMTR we should allocate to hedge funds, we first plot the efficient frontier of VIX futures index with hedge fund index (Figure 16).

Figure 16: Efficient Frontier with Addition of SPVIXMTR



We get the lowest volatility when we allocate approximately 10% VIX futures index to HFI, while for HFRX, the combination of 15% VIX futures index and 85% HFRX gives us the lowest risk.

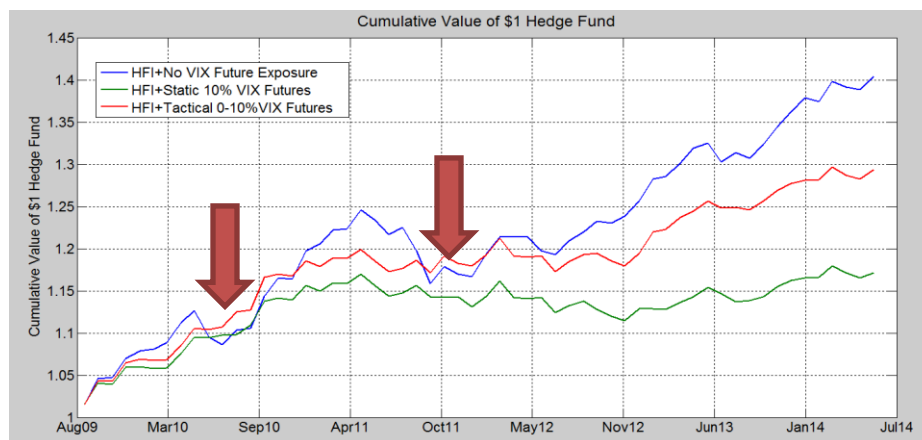
Based on our observations above, we can decide our allocation strategy. For the HFI, we have three allocation combinations:

1. HFI with no SPVIXMTR
2. HFI with static 10% SPVIXMTR
3. HFI with tactical 0-10% SPVIXMTR

Same as usual, we define the tactical allocation as following: if in the past quarter, the return of SPVIXMTR decreased by more than 20%, we set the weight of SPVIXMTR to 10%; if the return of SPVIXMTR increased by more than 20% in last quarter, we set the weight of SPVIXMTR to 0%; otherwise, the weight of SPVIXMTR equals to 5%.

Next, we plot the cumulative values of \$1 hedge fund portfolio based on these three combinations. From Figure 17, we can see the tactical allocation strategy gives us more stable cumulative returns. The value of portfolios with SPVIXMTR increases slower while with fewer fluctuations than how the value of HFI changes. The SPVIXMTR can protect hedge funds when big drawdown occurs.

Figure 17: Addition of S&P 500 Mid-Term Futures Index to HFI



For the HFRX, we also have three allocation combinations.

1. HFI with no SPVIXMTR
2. HFI with static 15% SPVIXMTR
3. HFI with tactical 0-15% SPVIXMTR

The tactical strategy is similar with the previous one. Except when the return of SPVIXMTR decreased by more than 20% in last quarter, we set the weight of SPVIXMTR to 15%.

As Figure 18 illustrates, the performance of tactical strategy is also more stable than hedge funds. When hedge fund returns falls down, the SPVIXMTR can help us to reduce lost.

Figure 18: Addition of S&P 500 Mid-Term Futures Index to HFRX

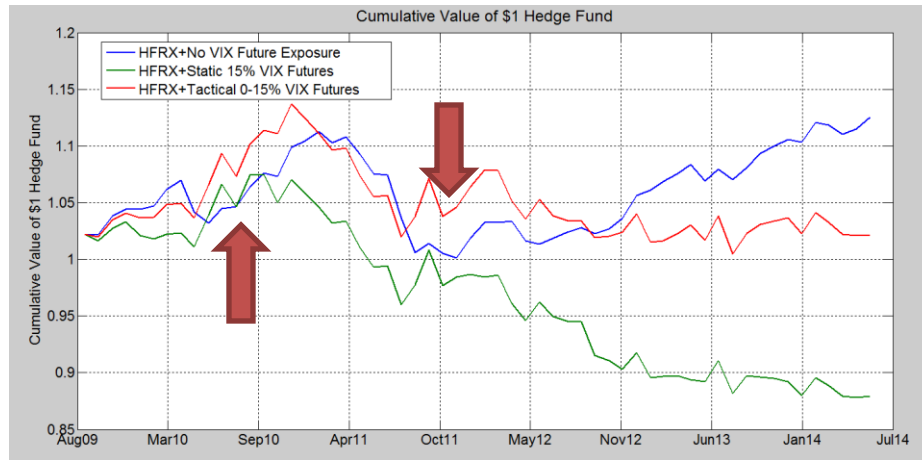


Table 8 gives us more information about the allocation strategies. Although portfolios with VIX futures exposure do not give superior returns, we can find that the tactical strategy not only gives us a lower annualized standard deviation, but it also improves the skewness and kurtosis of hedge fund portfolios.

Table 8: Summary of Portfolios with S&P 500 VIX Mid-Term Futures Index, 2009-2014

	HFI			HFRX		
	no SPVIXMTR	static 10% SPVIXMTR	tactical 0- 10% SPVIXMTR	no SPVIXMTR	static 15% SPVIXMTR	tactical 0- 15% SPVIXMTR
Risk-free rate: 0%						
Annualized Returns	7.41%	3.39%	5.56%	2.10%	-1.90%	0.55%
Annualized Std	0.047	0.033	0.036	0.042	0.036	0.036
Sharpe Ratio	1.568	1.028	1.549	0.503	-0.522	0.154
Skewness	-0.566	0.204	0.320	-0.925	-0.069	-0.273
Kurtosis	0.489	-0.214	0.266	1.206	-0.501	-0.247

In this section, we analyze VIX futures indices. It is obvious that during financial crisis, the addition of VIX futures indices effectively protect hedge fund portfolios. Starting from 2009, because economy is recovering from 2008 financial crisis, the performance of hedge fund is generally good. As a result, the return of SPVIXMTR keep decreasing, which is consistent with its negative correlation with hedge fund return, and therefore allocating SPVIXMTR index to hedge funds does not give us a better return. However, our analyses still provide support of risk reduction effect of VIX futures. We believe that when financial crisis occurs, the performance of hedge funds with VIX futures must be better than the hedge funds with no VIX futures.

6: Conclusions

We analyze VIX and hedge funds. Firstly, we confirm and expand the findings in Dash and Moran (2005) by conducting analyses on two indices, Credit Suisse and Hedge Fund Research Indices, and expand the end period of research from December 2004 to May 2014. To explore the relationship between VIX and hedge fund indices, we not only test the broad-based hedge fund indices, but also test the narrow hedge fund strategies. We find that broad-based hedge fund indices and most narrow hedge fund indices are negatively and asymmetrically correlated with VIX.

Then, we allocate VIX to broad-based hedge fund indices (HFI and HFRX). We use Dash and Moran (2005)'s tactical allocation strategy. We pay more attention to the period of 2008 financial crisis by including two sub-periods. Our finding is consistent with Dash and Moran's: allocating VIX index in hedge funds can protect hedge funds from major drawdowns. Specifically, cumulative investment value, annualized return, standard deviation, Sharpe ratio, skewness and kurtosis are improved.

We further expand Dash and Moran (2005) by conducting similar analyses on VIX futures. We use the S&P 500 VIX Mid-term Futures Index and the CBOE VIX Premium Strategy Index to represent VIX futures performance. The results suggest that the addition of VIX futures indices can mimic the consequence of adding VIX, including risk reduction and downside protection. Our analysis also shows that because some differences between VIX index and VIX futures, such as costs, VIX futures brings less significant beneficial impacts. Although the statistics during rising stage are not superior, VIX futures is a nice feasible tool used to improve and protect hedge funds, especially from sudden major drawdowns.

7: Limitations

The S&P 500 VIX Mid-Term Futures Index provides the risk exposure of longing VIX futures, but the index is only available since 2009. We find there is back-tested data till 2005 but is not available to us. Although we believe the index is a good proxy of investing in VIX futures, missing the period of 2008 financial crisis the index cannot provides us with the information of how VIX futures can hedge risk during downward.

The CBOE VIX Premium Strategy Index is different from S&P 500 VIX Mid-Term Futures Index in the way that it tracks the value of a portfolio invests in Treasury bill and shorts VIX futures. We have to short the index in order to get the long exposure of VIX futures. Moreover, introduced in November 2007, the data before that is back-tested. Therefore, some of the data we used are an estimated performance of the strategy and limitations of back testing, such as over fitting, could influence our analyses results.

Appendices

Appendix 1: Code 1

VIX Index and Hedge Fund Indices Correlations, Efficient Frontier and Allocation

Average and rolling 30-month correlations of Hedge Fund Returns with VIX changes

```
clear all;
close all;
clc;

%% Rolling 30-month correlations of Credit Suisse Hedge Fund Indices Returns with VIX
changes
filename1='HedgeFundData.xlsx';
[numHF,text] = xlsread(filename1);
ROR = numHF (1:end,[2:3:41]);
ROR = flip(ROR);

filename2='VIXdata.xlsx';
numVIX= xlsread(filename2,'Monthly returns');
numVIX= numVIX(:,1);

M=[numVIX, ROR];
corrla=corr(M);
avgCorrelation=[corrla(1,2:end)]';

Correlations=nan(168,14);
for i=31:168+30
    Mroll=M(i-30:i-1,:);
    corrla=corr(Mroll);
    Correlations(i-30,:)=corrla(1,2:end);
end

text=flip(text(:,1));
date=text(30:end-2,1);
date=datenum(date);

plot(date,Correlations(:,[1,2,3,4,5,6,10,11,12,13,14]));
ylabel('Rolling 30-month correlations of Credit Suisse Hedge Fund Indexes Returns with VIX
changes');
datetick('x', 'mmmyy');
title('Figure 1: Rolling 30-month correlations of HFI with VIX');

%% Rolling 30-month correlations of Hedge Fund Research Indices Returns with VIX changes
filename1='HFRdata.xlsx';
[ROR,text] = xlsread(filename1);
ROR = flip(ROR);

filename2='VIXdata.xlsx';
numVIX= xlsread(filename2,'Monthly returns');
```



```

numVIX=numVIX(:,1);

M=[numVIX, ROR];
corrla=corr(M);
avgCorrelation=[corrla(1,2:end)]';

Correlations=nan(168,5);
for i=31:198
    Mroll=M(i-30:i-1,:);
    corrla=corr(Mroll);
    Correlations(i-30,:)=corrla(1,2:end);
end

text=flip(text(:,1));
date=text(30:end-1,1);
date=datenum(date);
plot(date,Correlations(:,,:));
ylabel('Rolling 30-month Correlations of HFRX Hedge Fund Indexes Returns to VIX changes');
datetick('x', 'mmmyy');
title('Figure 2: Rolling 30-month correlations of HFRX with VIX');

```

Efficient Frontier VIX allocate to Hedge Fund Indices Year 1998 to 2014

```

clear all;
close all;
clc;

%% Efficient Frontier VIX allocate to HFI
filename1='HedgeFundData.xlsx';
[numHF,text] = xlsread(filename1);
ROR = numHF (1:end,2);
ROR = flip(ROR);

filename2='VIXdata.xlsx';
VIXReturn = xlsread(filename2,'Monthly returns');

avgMonthlyROR=mean(ROR);
avgMonthlyVIXReturn=mean(VIXReturn);
annualizedROR=avgMonthlyROR*12
annualizedVIXRet=avgMonthlyVIXReturn*12
M=[ROR,VIXReturn];
vcv=cov(M).*12

n=1;
for wgt = 0:0.01:1
    PortRet(n) = (1-wgt)*annualizedROR+wgt*annualizedVIXRet;
    stnd(n) = sqrt((1-wgt)^2*vcv(1,1)+wgt^2*vcv(2,2)+2*wgt*(1-wgt)*vcv(1,2));
    n=n+1;
end

```

```

plot(std,PortRet,'b');
title('Efficient Frontier Hedge Fund Index with VIX Index, Jan 1998 to May 2014');
xlabel('Annualized Std');
ylabel('Annualized Return');
hold on

%% Efficient Frontier VIX allocate to HFRX
filename1='HFRData.xlsx';
[numHF,text] = xlsread(filename1);
ROR = numHF (1:end,1);
ROR = flip(ROR*0.01);

filename2='VIXdata.xlsx';
VIXReturn = xlsread(filename2,'Monthly returns');

avgMonthlyROR=mean(ROR);
avgMonthlyVIXReturn=mean(VIXReturn);
annualizedROR=avgMonthlyROR*12
annualizedVIXRet=avgMonthlyVIXReturn*12
M=[ROR,VIXReturn];
vcv=cov(M).*12

n=1;
for wgt = 0:0.01:1
    PortRet(n) = (1-wgt)*annualizedROR+wgt*annualizedVIXRet;
    std(n) = sqrt((1-wgt)^2*vcv(1,1)+wgt^2*vcv(2,2)+2*vcv(1,2)*wgt*(1-wgt));
    n=n+1;
end
plot(std,PortRet,'r');

```

Addition of VIX Index to Hedge Fund Index January 1998 - May 2014

```

clear all;
close all;
clc;

%% Addition of VIX Index to HFI January 1998 - May 2014
% tactical allocation 0% 5% 10%
filename1='HedgeFundData.xlsx';
[numHF,text] = xlsread(filename1);
ROR = numHF (1:end,2);
ROR = flip(ROR);

filename2='VIXdata.xlsx';
VIXReturn= xlsread(filename2,'Monthly returns');
VIXQReturn= xlsread(filename2,'Q returns');

wgt(1:3,1)=0.05;
n=4;
for i=1:65;

```

```

if VIXQReturn(i,2)>0.2
    wgt(n:n+2,1)=0;
else if VIXQReturn(i,2)<-0.2
    wgt(n:n+2,1)=0.1;
else
    wgt(n:n+2,1)=0.05;
end
end
n=n+3;
end

cPortRet=nan(197,1);
PortRet=nan(197,1);

PortRet(1,1)=(1-wgt(1))*ROR(1,1)+wgt(1)*VIXReturn(1,1);
cPortRet(1,1)=PortRet(1,1)+1;
for i=2:size(ROR)
    PortRet(i,1)=(1-wgt(i))*ROR(i,1)+wgt(i)*VIXReturn(i,1);
    cPortRet(i,1)=(PortRet(i,1)+1)*cPortRet(i-1,1);
end

text=flip(text(:,1));
date=text(1:end-2,1);
date=datenum(date);
plot(date,cPortRet,'m');
title('Portfolio Value of $1 Investment with VIX index, January 1998 to May 2014')
datetick('x', 'mmmyy');
hold on

% no vix and static allocation
cPortRet=nan(197,11);
PortRet=nan(197,11);
wgt=0;

for j=1:11
    PortRet(1,:)=(1-wgt)*ROR(1,1)+wgt*VIXReturn(1,1);
    cPortRet(1,:)=PortRet(1,:)+1;
    for i=2:size(ROR)
        PortRet(i,j)=(1-wgt)*ROR(i,1)+wgt*VIXReturn(i,1);
        cPortRet(i,j)=(PortRet(i,j)+1)*cPortRet(i-1,j);
    end
    wgt = wgt+0.01;
end

plot(date, cPortRet(:,[1 6 11]));
datetick('x', 'mmmyy');

%% Addition of VIX Index to HFRX January 1998 - May 2014
% tactical allocation 0% 5% 10%
filename1='HFRdata.xlsx';

```

```

[numHF,text] = xlsread(filename1);
ROR = numHF (1:end,1);
ROR = flip(ROR*0.01);

filename2='VIXdata.xlsx';
VIXReturn= xlsread(filename2,'Monthly returns');
VIXQReturn= xlsread(filename2,'Q returns');

wgt(1:3,1)=0.05;
n=4;
for i=1:65;
    if VIXQReturn(i,2)>0.2
        wgt(n:n+2,1)=0;
    else if VIXQReturn(i,2)<-0.2
        wgt(n:n+2,1)=0.1;
    else
        wgt(n:n+2,1)=0.05;
    end
end
n=n+3;
end

cPortRet=nan(197,1);
PortRet=nan(197,1);

PortRet(1,1)= (1-wgt(1))*ROR(1,1)+wgt(1)*VIXReturn(1,1);
cPortRet(1,1)=PortRet(1,1)+1;
for i=2:size(ROR)
    PortRet(i,1) = (1-wgt(i))*ROR(i,1)+wgt(i)*VIXReturn(i,1);
    cPortRet(i,1) = (PortRet(i,1)+1)*cPortRet(i-1,1);
end

text=flip(text(:,1));
date=text(1:end-1,1);
date=datenum(date);
plot(date,cPortRet,'m');
title('Portfolio Value of $1 Investment in HFRX and VIX index, January 1998 to May 2014')
datetick('x', 'mmyy');
hold on

% no vix and static allocation
cPortRet=nan(197,11);
PortRet=nan(197,11);
wgt=0;

for j=1:11
    PortRet(1,:)= (1-wgt)*ROR(1,1)+wgt*VIXReturn(1,1);
    cPortRet(1,:)=PortRet(1,:)+1;
    for i=2:size(ROR)
        PortRet(i,j) = (1-wgt)*ROR(i,1)+wgt*VIXReturn(i,1);
        cPortRet(i,j) = (PortRet(i,j)+1)*cPortRet(i-1,j);
    end
end

```

```

    %std(n) = sqrt((1-wgt)^2*vcv(1,1)+wgt^2*vcv(2,2)+2*vcv(1,2)*wgt*(1-wgt));
end
    wgt = wgt+0.01;
end

plot(date, cPortRet(:, [1 6 11]));
datetick('x', 'mmmyy');

```

Appendix 2: Code 2

VPD and Hedge Fund Indices Correlations, Efficient Frontier and Allocation

Adjustment of VPD monthly return

```
clear all;
close all;
clc

filename='VIXfuturesData.xlsx';
[num,text]= xlsread(filename,'vpddailyprice');
Datetext = datestr(text(2:end,1),'yyyy/mm/dd');
Dret=price2ret(num(:,1),[],'Periodic')+1;
```

```
filename2='TreasuryBills.xlsx';
TBret= xlsread(filename2);
TBret=TBret(:,6);
```

```
i = length(Dret(:,1));
k=1;
MRet = nan(119,1);
MRet(1) = Dret(1);
for j = 3:i
    if Datetext(j-1,1:4) == Datetext(j,1:4)
        if Datetext(j-1,6:7) == Datetext(j,6:7)
            MRet(k) = Dret(j-1)*MRet(k);
        else
            k=k+1;
            MRet(k)=Dret(j-1);
        end
    else
        k=k+1;
        MRet(k)=Dret(j-1);
        j=j+1;
    end
end
```

```
%adjst for returns of 3-month Treasury bills
MRet=MRet-TBret;
AdjMonthRet=MRet-1;
```

Average and rolling 30-month correlations of Hedge Fund Returns with VPD

```
%% Average and rolling 30-month correlations of HFI with VPD
filename1='HedgeFundData.xlsx';
[numHF,text] = xlsread(filename1);
ROR = numHF (1:end,2);
```

```

ROR = flip(ROR);
ROR = ROR(79:end,:);

M=[AdjMonthRet,ROR];
Correlations=nan(90,1);
for i=31:size(AdjMonthRet)+1
    Mroll=M(i-30:i-1,:);
    corrla=corr(Mroll);
    Correlations(i-30,1)=corrla(1,2);
end

averageCorr=corr(M);
averageCorrelation(1,1)=averageCorr(1,2);
text=flip(text(:,1));
date=text(79+29:end-2,1);
date=datetime(date);

figure(1);
plot(date,Correlations(:,1));
ylabel('Rolling 30-month correlations of Hedge fund with VPD');
datetick('x', 'mmmyy');
title('Rolling 30-month correlations of Hedge fund with VPD');
hold on

%% Average and rolling 30-month correlations of HFRX with VPD
filename1='HFRData.xlsx';
[numHF,text] = xlsread(filename1);
ROR = numHF (1:end,1);
ROR = flip(ROR*0.01);
ROR = ROR(79:end,:);

M=[AdjMonthRet,ROR];
Correlations=nan(90,1);
for i=31:size(AdjMonthRet)+1
    Mroll=M(i-30:i-1,:);
    corrla=corr(Mroll);
    Correlations(i-30,1)=corrla(1,2);
end
averageCorr=corr(M);
averageCorrelation(2,1)=averageCorr(1,2);
plot(date,Correlations(:,1),'r');

```

Addition of VPD to Hedge Fund Index January 2007 – December 2009

```

%% Addition of VPD to HFI January 2007 – December 2009
clear all;
close all;
clc

filename='VIXfuturesData.xlsx';

```

```

AdjMonthRet= xlsread(filename,'VPDR');

filename1='HedgeFundData.xlsx';
[numHF,text]= xlsread(filename1);
ROR = numHF (1:end,2);
ROR = flip(ROR);
ROR = ROR(79+30:79+30+35,:);
text=flip(text(:,1));
date=text(79+30:79+30+35,1);
date=datenum(date);

%% tactical
filename='VIXfuturesData.xlsx';
VPDQReturn= xlsread(filename,'VPDQreturns');

wgt(1:3,1)=-0.05;
n=4;
for i=1:39;
    if VPDQReturn(i,1)>0.2
        wgt(n:n+2,1)=0;
    else if VPDQReturn(i,1)<-0.2
        wgt(n:n+2,1)=-0.1;
    else
        wgt(n:n+2,1)=-0.05;
    end
end
n=n+3;
end

wgt=wgt(30:30+35);
VPDReturn = AdjMonthRet(30:30+35);
PortRetT(1,1)= (1-wgt(1))*ROR(1,1)+wgt(1)*VPDReturn(1,1);
cPortRetT(1,1)=PortRetT(1,1)+1;

for i=2:size(ROR)
    PortRetT(i,1) = (1-wgt(i))*ROR(i,1)+wgt(i)*VPDReturn(i,1);
    cPortRetT(i,1) = (PortRetT(i,1)+1)*cPortRetT(i-1,1);
end

plot(date,cPortRetT,'m');
title('Portfolio Value of $1 Investment in HFRX and VPD, Januar 2007 to December 2009')
datetick('x', 'mmmyy');
hold on

%% Static allocation
cPortRet=nan(36,3);
PortRet=nan(36,3);
wgt=0;

for j=1:3
    PortRet(1,j)= (1-wgt)*ROR(1,1)+wgt*VPDReturn(1,1);

```



```

cPortRet(1,j)=PortRet(1,j)+1;
for i=2:size(ROR)
    PortRet(i,j) = (1-wgt)*ROR(i,1)+wgt*VPDReturn(i,1);
    cPortRet(i,j) = (PortRet(i,j)+1)*cPortRet(i-1,j);
end
wgt = wgt-0.05;% short
end
monthlyRet(:,1:3)=PortRet;

plot(date,cPortRet(:,[1:3]));
datetick('x', 'mmmyy');

%% Addition of VPD to HFRX January 2007 – December 2009
clear all;
close all;
clc

filename='VIXfuturesData.xlsx';
AdjMonthRet= xlsread(filename,'VPDR');

filename1='HFRData.xlsx';
[numHF,text] = xlsread(filename1);
ROR = numHF (1:end,1);
ROR = flip(ROR*0.01);
ROR = ROR(79+30:79+30+35,:);
text=flip(text(:,1));
date=text(79+30:79+30+35,1);
date=datenum(date);

%% tactical
filename='VIXfuturesData.xlsx';
VPDQReturn= xlsread(filename,'VPDQreturns');

wgt(1:3,1)=-0.05;
n=4;
for i=1:39;
    if VPDQReturn(i,1)>0.2
        wgt(n:n+2,1)=0;
    else if VPDQReturn(i,1)<-0.2
        wgt(n:n+2,1)=-0.1;
    else
        wgt(n:n+2,1)=-0.05;
    end
end
n=n+3;
end
wgt=wgt(30:30+35);
VPDReturn = AdjMonthRet(30:30+35);
PortRetT(1,1)= (1-wgt(1))*ROR(1,1)+wgt(1)*VPDReturn(1,1);
cPortRetT(1,1)=PortRetT(1,1)+1;

```

```

for i=2:size(ROR)
    PortRetT(i,1) = (1-wgt(i))*ROR(i,1)+wgt(i)*VPDReturn(i,1);
    cPortRetT(i,1) = (PortRetT(i,1)+1)*cPortRetT(i-1,1);
end

plot(date,cPortRetT,'m');
title('Portfolio Value of $1 Investment in HFRX and VPD, January 2007 to December 2009')
datetick('x', 'mmmyy');
hold on

%% Static allocation
cPortRet=nan(36,3);
PortRet=nan(36,3);

wgt=0;
for j=1:3
    PortRet(1,j) = (1-wgt)*ROR(1,1)+wgt*VPDReturn(1,1);
    cPortRet(1,j)=PortRet(1,j)+1;
    for i=2:size(ROR)
        PortRet(i,j) = (1-wgt)*ROR(i,1)+wgt*VPDReturn(i,1);
        cPortRet(i,j) = (PortRet(i,j)+1)*cPortRet(i-1,j);
    end
    wgt = wgt-0.05;
end
monthlyRet(:,1:3)=PortRet;

plot(date,cPortRet(:,[1:3]));
datetick('x', 'mmmyy');

```

Appendix 3: Code 3

S&P 500 Mid-Term VIX Futures Index and Hedge Fund Indices Correlations, Efficient Frontier and Allocation

```
%Import S&P 500 Midterm VIX futures index data from Excel
filename='VIXfuture_MidTerm.xlsx';
[num,text]= xlsread(filename);
```

```
%Set date type
Datetext = datestr(text(2:end,1),'yyyy/mm/dd');
%Calculate the daily return
DailyRet = price2ret(num(1:end),[],'Periodic')+1;
%Count number of days
i = length(DailyRet(:,1));
```

```
%Calculate monthly return
k=1;
Ret = nan(58,1);
Ret(1) = DailyRet(1);
```

```
for j = 3:i
    if Datetext(j-1,1:4) == Datetext(j,1:4)
        if Datetext(j-1,6:7) == Datetext(j,6:7)
            Ret(k) = DailyRet(j-1)*Ret(k);
        else
            k=k+1;
            Ret(k)=DailyRet(j-1);
        end
    else
        k=k+1;
        Ret(k)=DailyRet(j-1);
        j=j+1;
    end
end
MonthRet=Ret(1:end)-1;
```

```
%Import CSHFI data from Excel
filename='HedgeFundData.xlsx';
[num2, text2]= xlsread(filename);
```

```
CSROR = num2 (1:end-1, [2:3:41]);
CSROR = flip(CSROR);
```

```
%Calculate rolling correlation b/w CSHFI&SPVIXMTR
CorrMatrixCS = nan(29,14);
```

```
for j = 1:14
    for i = 30:58
```

```

        CorrMatrixCS(i-29,j) = corr(MonthRet(i-29:i), CSROR(i+187-29:i+187, j));
    end
end

CSdateLabel = flip(text2(3:248,1));
CSDate = datenum(CSdateLabel(218:246));

%Import HFR data from Excel
filename='hfrx_historical_Summary.xlsx';
[num3, text3]= xlsread(filename);
HFRERROR = flip(num3);
HFRERROR=HFRERROR*0.01;

%Calculate rolling correlation b/w HFR&SPVIXMTR
CorrMatrixHFR = nan(29,5);

for j = 1:5
    for i = 30:58
        CorrMatrixHFR(i-29,j) = corr(MonthRet(i-29:i), HFRERROR(i+139-29:i+139, j));
    end
end

HFRdateLabel = CSdateLabel(50:end);
HFRDate = datenum(HFRdateLabel(169:end));

% Plot the rolling correlation
figure(1)
plot(CSDate,CorrMatrixCS(:,1),HFRDate,CorrMatrixHFR(:,1));
datetick('x', 'mmmyy', 'keepticks')

% Calculate average yearly return for CS Hedge fund.
n=1;
for i = 1:12:240
    AnnualROR(n) = sum(CSROR(i:i+11,1));
    n=n+1;
end
AvgCSROR = mean(AnnualROR(17:20));

%Calculate average yearly return for VIX index.
n=1;
for i = 6:12:53
    AnnualMonthRet(n) = sum(MonthRet(i:i+11,1));
    n=n+1;
end
AvgVIXRet = mean(AnnualMonthRet);

%Calculate portfolio return and standard deviation
n=1;
CScovVIX=cov(AnnualROR(17:20),AnnualMonthRet);

```

```

for wgt = 0:0.001:0.15
    PortRet(n) = (1-wgt)*AvgCSROR+wgt*AvgVIXRet;
    stnd(n) = sqrt((1-
wgt)^2*var(AnnualROR(17:20))+wgt^2*var(AnnualMonthRet)+2*CScovVIX(1,2)*wgt*(1-
wgt));
    n=n+1;
end

% Calculate average yearly return for HFR.
n=1;
for i = 1:12:192
    AnnualHFRROR(n) = sum(HFRROR(i:i+11,1));
    n=n+1;
end
AvgHFRROR = mean(AnnualHFRROR(13:16));

%Calculate portfolio return and standard deviation
n=1;
HFRcovVIX=cov(AnnualHFRROR(13:16),AnnualMonthRet);

for wgt = 0:0.001:0.15
    HFRPortRet(n) = (1-wgt)*AvgHFRROR+wgt*AvgVIXRet;
    HFRstnd(n) = sqrt((1-
wgt)^2*var(AnnualHFRROR(13:16))+wgt^2*var(AnnualMonthRet)+2*HFRcovVIX(1,2)*wgt*(
1-wgt));
    n=n+1;
end

%Plot efficient frontier
figure(3);
plot(stnd,PortRet,HFRstnd,HFRPortRet);

% Calculate cumulative return with static VIX

PortMonthRet=zeros(58,11);
m=1;

for wgt2 = 0:0.01:0.2
    PortMonthRet(1,m)= (1-wgt2)*CSROR(188,1)+wgt2*MonthRet(1)+1;
    PortMonthRet(2,m) = ((1-
wgt2)*CSROR(189,1)+wgt2*MonthRet(2)+1)*(PortMonthRet(1,m));
    for n=2:57
        PortMonthRet(n+1,m) = ((1-
wgt2)*CSROR(n+187+1,1)+wgt2*MonthRet(n+1)+1)*(PortMonthRet(n,m));

    end
    m=m+1;
end

% Import SPVIXMTR quarterly changes data from Excel
filename='QChange_VIXfutureMT.xlsx';

```

```
[Qchange,Quater]= xlsread(filename);
```

```
% Calculate cumulative return with tactical VIX
```

```
PortMonthRet2=zeros(58,1);
```

```
wgt3 = 0.05;
```

```
PortMonthRet2(1)= (1-wgt3)*CSROR(188,1)+wgt3*MonthRet(1)+1;
```

```
PortMonthRet2(2) = ((1-wgt3)*CSROR(189,1)+wgt3*MonthRet(2)+1)*(PortMonthRet2(1));
```

```
PortMonthRet2(3) = ((1-wgt3)*CSROR(190,1)+wgt3*MonthRet(3)+1)*(PortMonthRet2(2));
```

```
PortMonthRet2(4) = ((1-wgt3)*CSROR(191,1)+wgt3*MonthRet(4)+1)*(PortMonthRet2(3));
```

```
PortMonthRet2(5) = ((1-wgt3)*CSROR(192,1)+wgt3*MonthRet(5)+1)*(PortMonthRet2(4));
```

```
k=1;
```

```
for n=5:57
```

```
    if mod(n+187,3) == 0
```

```
        if Qchange(k)>0.2
```

```
            wgt3 = 0;
```

```
        else if Qchange(k)<-0.2
```

```
            wgt3 = 0.1;
```

```
        else
```

```
            wgt3 = 0.05;
```

```
        end
```

```
    end
```

```
    k=k+1;
```

```
end
```

```
PortMonthRet2(n+1) = ((1-
```

```
wgt3)*CSROR(n+188,1)+wgt3*MonthRet(n+1)+1)*(PortMonthRet2(n));
```

```
end
```

```
% Plot cumulative returns
```

```
figure(4)
```

```
plot(datenum(CSdateLabel(189:246)),PortMonthRet(:,1),datenum(CSdateLabel(189:246)),PortMonthRet(:,11),datenum(CSdateLabel(189:246)),PortMonthRet2);
```

```
datetick('x', 'mmmyy', 'keepticks')
```

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